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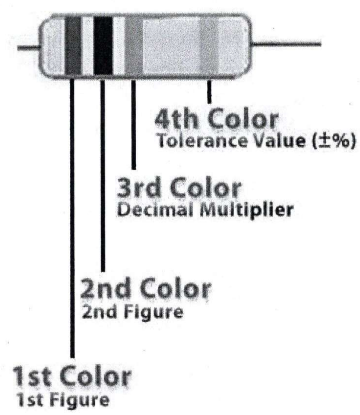
Lab 5 : Kirchhoff's Rules-PHY 152

Objective: Application of Kirchhoff's Rules
Equipment: Power supply, resistors, Voltmeter/ current meter
Kirchhoff's Laws:

> **Junction rule**: At a junction where a current path divides into two or more branches, Sum of incoming currents = Sum of outgoing currents.
> **Loop rule**: Over any closed loop, Sum of voltage drops over all circuit elements=0

Resistor Color Code:

Color	Digit	Multiplier	Tolerance (%)
Black	0	10^0 (1)	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
(none)			20



Above shown resistor's colors are Brown, Black, Orange and Golden so its value is **10** X 1000 = 10000Ω or 10KΩ with a tolerance of ±5%

Procedure:

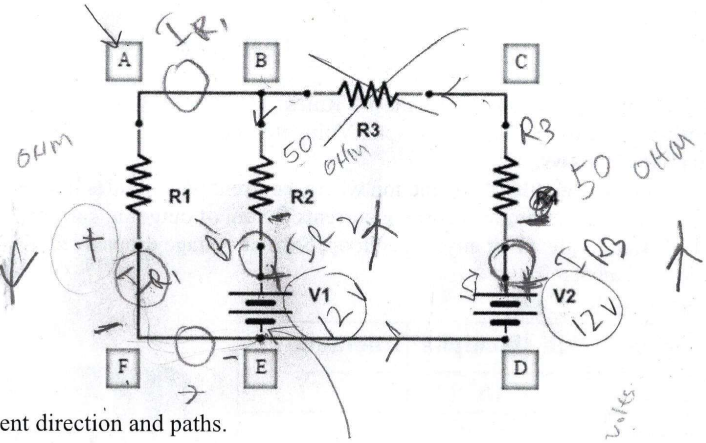
1. Analyze the following electrical circuit by applying Kirchhoff's rules to calculate the currents (magnitude and direction) through each resistor of known resistance. You may use two different voltages.

$I_{R_3} = 0.61$

$10\Omega/50\Omega/10\Omega + 0.61$

$10\Omega/50\Omega/50\Omega\ 0.22$

10 OHM



Draw your current direction and paths.
Analysis:

Write the Junction Rule: $I_1 = I_2 + I_3$

$\vec{I_1} = \overleftarrow{I_2} + \overleftarrow{I_3}$

@ 12 volts

Write the Loop Rules (should be 3):

I_{R_2}

$0.22 = I_{R_1}$ $I_{R_3} = 0.22$

E

$\sum \Delta V_i = 0$

$\sum \Delta V_i = I_R = I_{R_2} + I_{R_3}$

Choose 4 resistors to be in your system. **<u>Estimate</u>** from your loop and junction rules what the current is through each R_1, R_2, R_3, R_4. $i = \frac{V}{R}$

Resistor	Resistance (Ω)	Current through Resistor (A)
R_1	50 Ω	12V ÷ 50 = .24A
R_2	50 Ω	12V ÷ 50 = .24A
R_3	50 Ω	12V ÷ 50 = .24A
R_4		

Verify by measuring the currents and measure the voltage drop over the resistors. Compare the estimated current with the measured values (use absolute values when comparing).

@

	V_1 SWITCHED	V_1/V_2 SWITCHED
I_{R1}	-.31	-.229
I_{R2}	-.3	-.22
I_{R3}	+.3	-.21

0.031A

Measurement:

Potential difference (V) Boxed letters Diffenuce	Current through Resistor (A)	Direction of current (+/-)	% error between measured and theoretical (above) values of Current
$V_A - V_F$ = 4.67	I_{R1} = .231 A	+	3.9 %
$V_B - V_E$ = - 11.62	I_{R2}= .22 A	+	9.09%
~~$V_B - V_C$ =~~	I_{R3}= .22 A	+	9.09 %
$V_C - V_D$ = -11.49	I_{R4}=		

mill ⟶

Change the polarity of one of the batteries and reanalyze the circuit. Measure the currents through the resistors and verify by measuring them.

Analysis:

Write the Junction Rule:

JUNCTION 1

$I_E \to I_D = I_1 = \frac{V}{R_1} = \frac{24v}{50} = .48A$

JUNCTION 2

NODE 1

$V_B \to V_A = I_2 = \frac{V}{R_2} = \frac{12v}{50} = .24A$

NODE 2

$V_C \to V_B = I_3 = \frac{V}{R_3} = \frac{12v}{50} = .24A \longrightarrow .24A + .24A = .48A$

$I_2 + I_3 = I_1$

-OR-

$\sum I_{in} = \sum I_{out}$

$I_2 = 12V$ R_1 R_2 R_3 $I_3 = 12v$

$I_3 = 12v + 12v$

Loop Rules

LOOP (1)

EBAF

$50I_2 = 10I_1 + 50I_3$

LOOP (2)

ABEFA

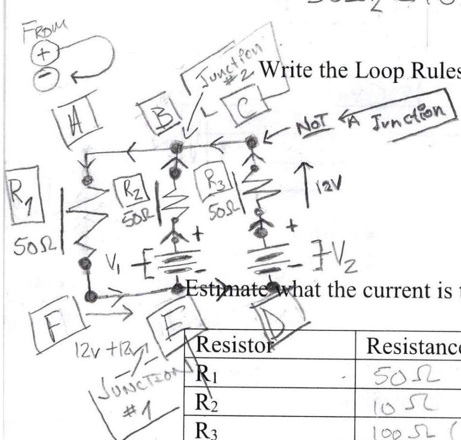
$12 - 10I_1 - 50I_2 = 0$

LOOP (3)

DCBE

$12 - 50I_3 - 10I_1 = 0$

Write the Loop Rules (should be 3).



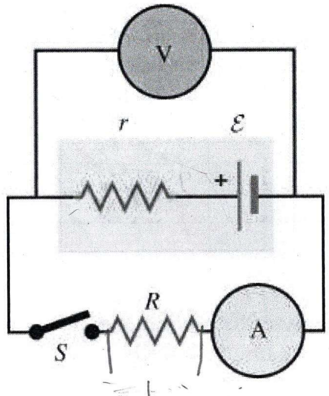
Estimate what the current is through R_1, R_2, R_3, R_4.

Resistor	Resistance (Ω)	Current through Resistor (A)
R_1	50 Ω	6V ÷ 50 = .12 A
R_2	10 Ω	6V ÷ 10 = .6 A
R_3	100 Ω (Series)	6V ÷ 100 = .06 A
R_4	100 Ω (Parallel)	6V ÷ 100 = .06 A

How did changing the polarity of one of the batteries affect the circuit?

Same number, but resulted in a change in sign. (+ → -)

Internal Resistance of a battery



Recall terminal voltage of a battery V = Ɛ - Ir. The terminal voltage of a battery is smaller than the electromotive force of the battery because of the internal resistance inside the battery.

The Kirchoff equations for this circuit is
0 = Ɛ - Ir - IR

Connect a Voltmeter across the terminals of the battery and read the voltage. (do not setup circuit yet for this step, it is battery only.)

V= 12 V

Connect battery to an external resistor R, a switch, and a Voltmeter as shown. Measure the Voltage across the terminal of the battery and the current in the table below for 5 different resistors. 2 TRIALS for each resistor

TRIAL 1   TRIAL 2   * x 10^{-6} (current)   ** x 10^{-3} (voltage)

	Resistance (Ω)	Current (A)*	Voltage (V)**
R_1	10 Ω (1% Tolerance)	1 .00129 A, .0121V	2 .000117 A, .0117V
R_2	100 Ω (SERIES)	1 .000122 A, .0058V	2 .000124 A, .006V
R_3	50 Ω	1 .000115 A, .0028V	2 .000112 A, .0027V
R_4	100 Ω (Parallel)	1 .000116 A, .0116V	2 .00011 A, .011V

What do you notice about the relationship between the Voltage and the Current?

FOR R_2

$V = IR$. $R = \frac{V}{I} = \frac{.0028}{.000115} = 24.35\,\Omega$ Voltage and current are inversely-proportional.

Plot Current vs Voltage (dependent). What is your value for the slope? 4.881

What does the slope value represent? (look at your terminal voltage equation)

The voltage increases by 4.881 units for each unit (ampere) increase in the current.

What is your y-intercept? 0.0062

What does the y-intercept value represent?

$\mathcal{E} - mI \cdot r = V^{(I \cdot R)}$
$mx + b = y$

Additional resistance (internal resistance of the battery)

1 Internal resistance value $r = .0062$ 2 EMF $I \cdot r = \mathcal{E}$ $\mathcal{E} = 2.42 \times 10^{-6}$ (Avg.)

Now plot the inverse of the Current (1/I) vs the Resistance (R) (dependent variable) used.

What is your value for slope? -0.0982

To what does the slope value correspond? (look at your Kirchoff's Rules equation)

The inverse of the current decreases for every 1 unit (Ω) increase in the resistance.

$\rightarrow r = 81.406$

What is your y-intercept? 81.406 $\rightarrow I \cdot r = 536048.53$ (Avg)

To what does the y-intercept value correspond?

The y-intercept matches the increase of internal resistance with each increase in $\frac{1}{\text{Current}}$ (or, equivalently, with every 1-unit decrease in the current).

Compare your internal resistance values from each plotting method. Are they close? Why or why not? The y-intercept of the inverse plot differs by a factor of 1000 from the Voltage vs Current plot. And that makes SENSE, since the current itself differs from its inverse by a factor of 1 million. Internal resistance reflects current, and Vice-Versa.

$\mathcal{E} = I r$ ← internal resistance; ↑ current

Compare your electromotive force (Ɛ) values from each plotting method. Are they close? Why or why not?

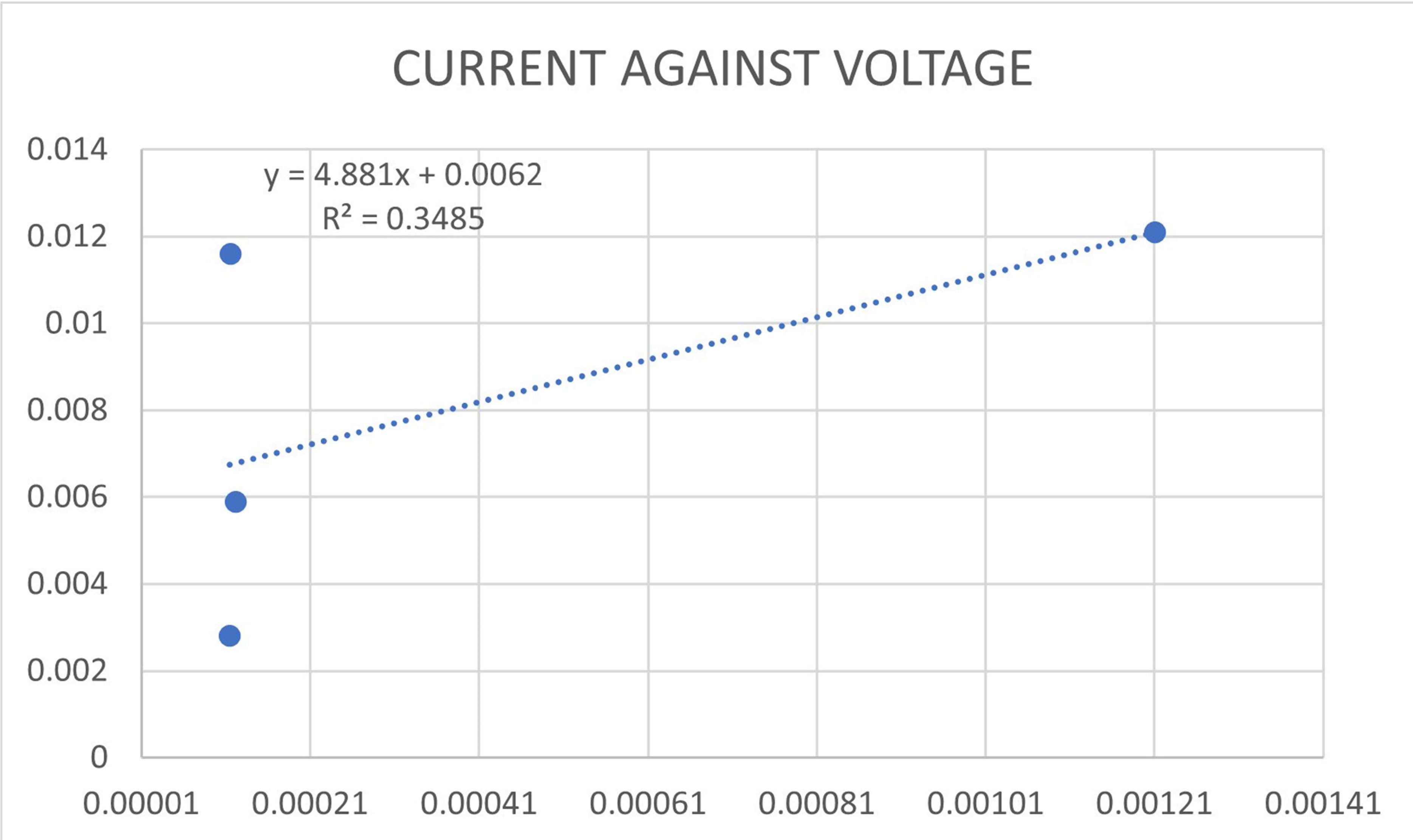
No, they are polar opposites — given the smallness of the Amperage, it's obvious the EMF will be much larger in the plot of Resistance against Current (I) as an inverse.

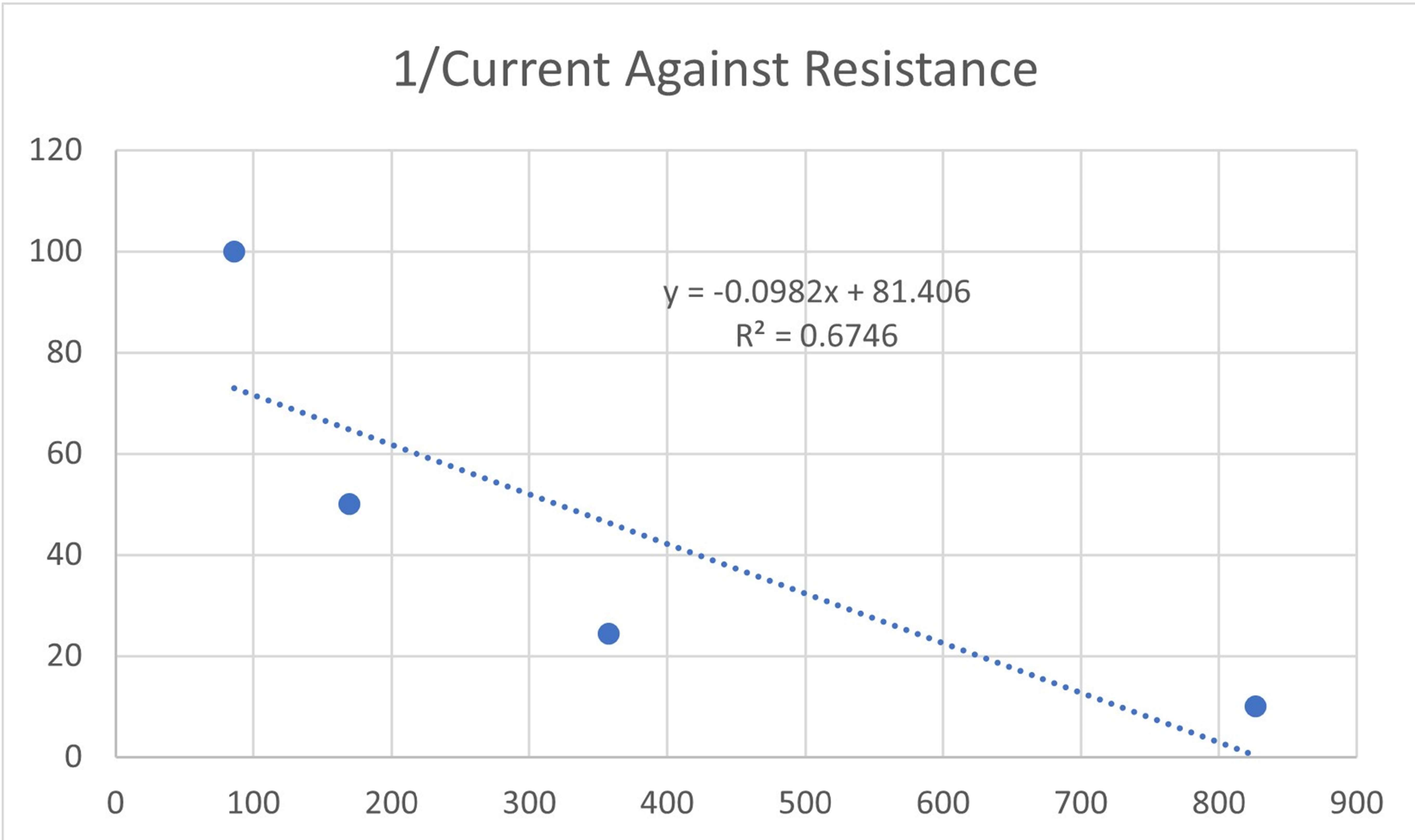
I've provided the EMF_0 for both plots as an average. As current (or $\frac{1}{\text{current}}$) and internal resistance increase so will the electro-motive force.

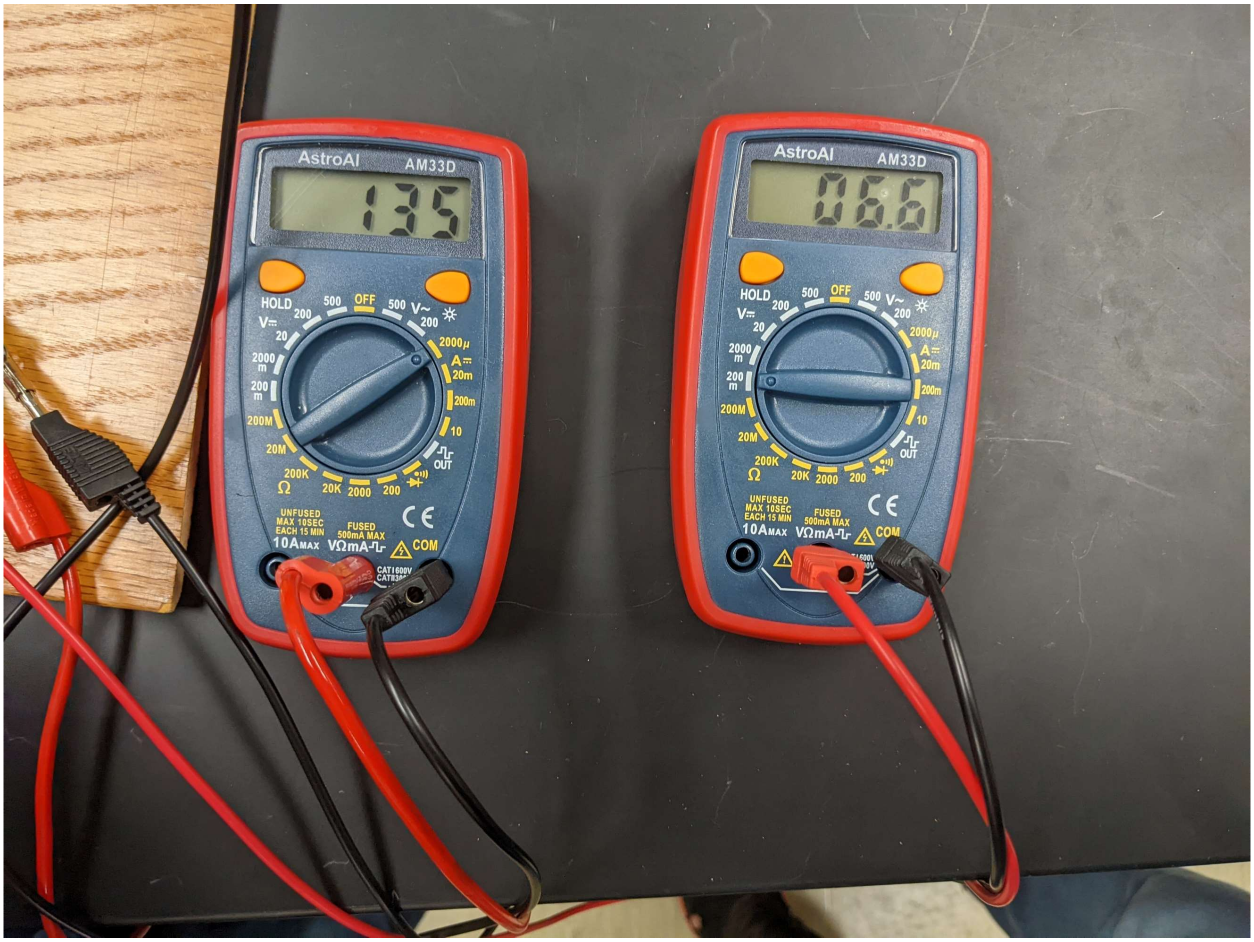
Summarize what all you learnt through using Kirchoff's laws and the internal resistance of a battery. (3-5 sentences)

Kirchoff's laws are typically used to measure multi-branch circuits. Applying them to simpler set-ups is sometimes problematic, but this lab exercise reveals alot about how current travels between nodes. Deriving the different Loop Rules, for instance, forces an understanding of where the current is in a circuit, where it's going, and how it's altered between nodes and across resistors.

I also gained an appreciation for the practice of plotting with Voltage, rather than current, as the dependent variable — a practice that seems very unnatural. However, I learned, in answering the post-lab questions that swapping the axes this way isolates the Internal Resistance of the battery as the y-intercept, which makes calculation of EMF only a matter of multiplying a current on that circuit with the y-intercept.


CURRENT AGAINST VOLTAGE
y = 4.881x + 0.0062
R² = 0.3485
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0.00001
0.00021
0.00041
0.00061
0.00081
0.00101
0.00121
0.00141


1/Current Against Resistance
y = -0.0982x + 81.406
R² = 0.6746
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900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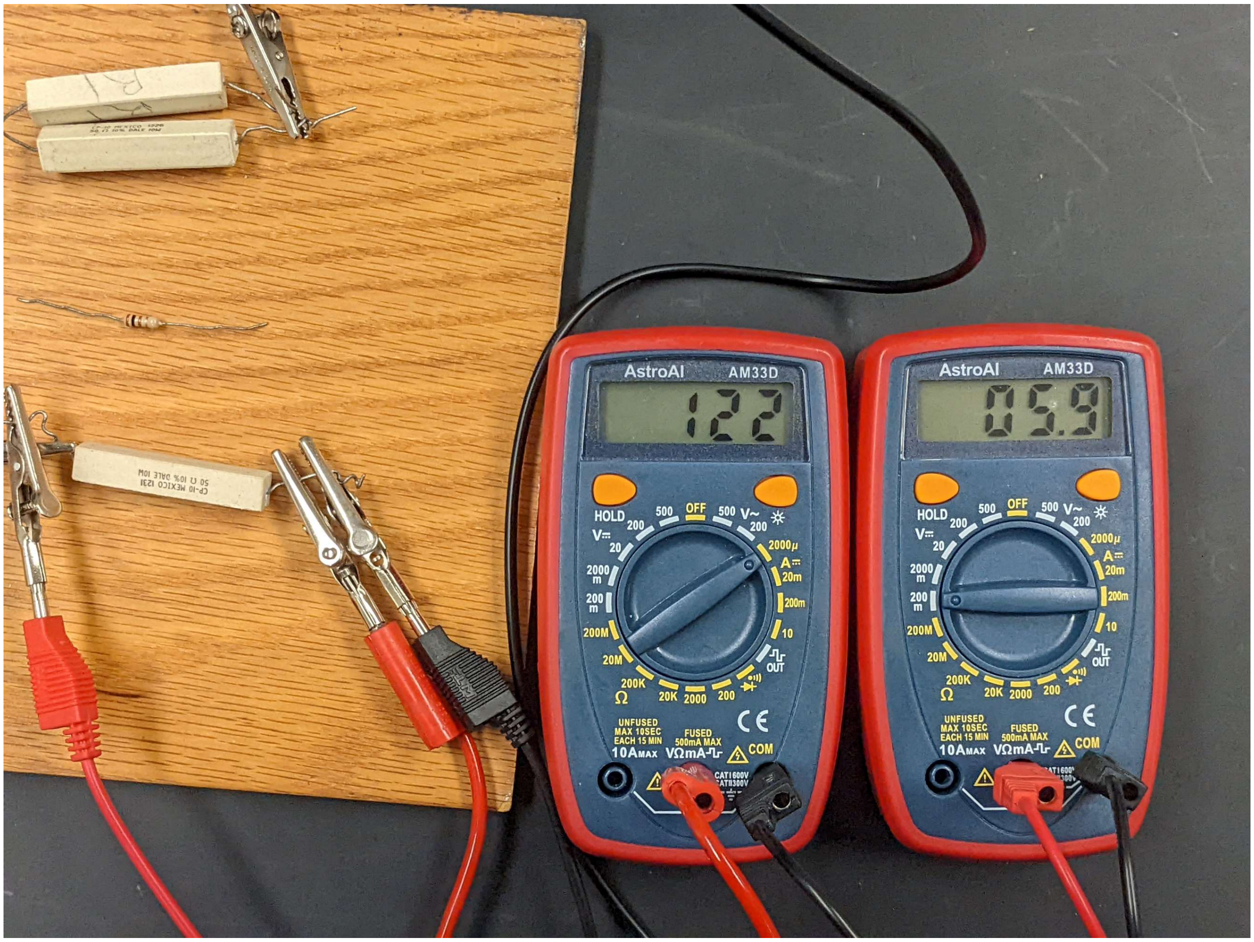
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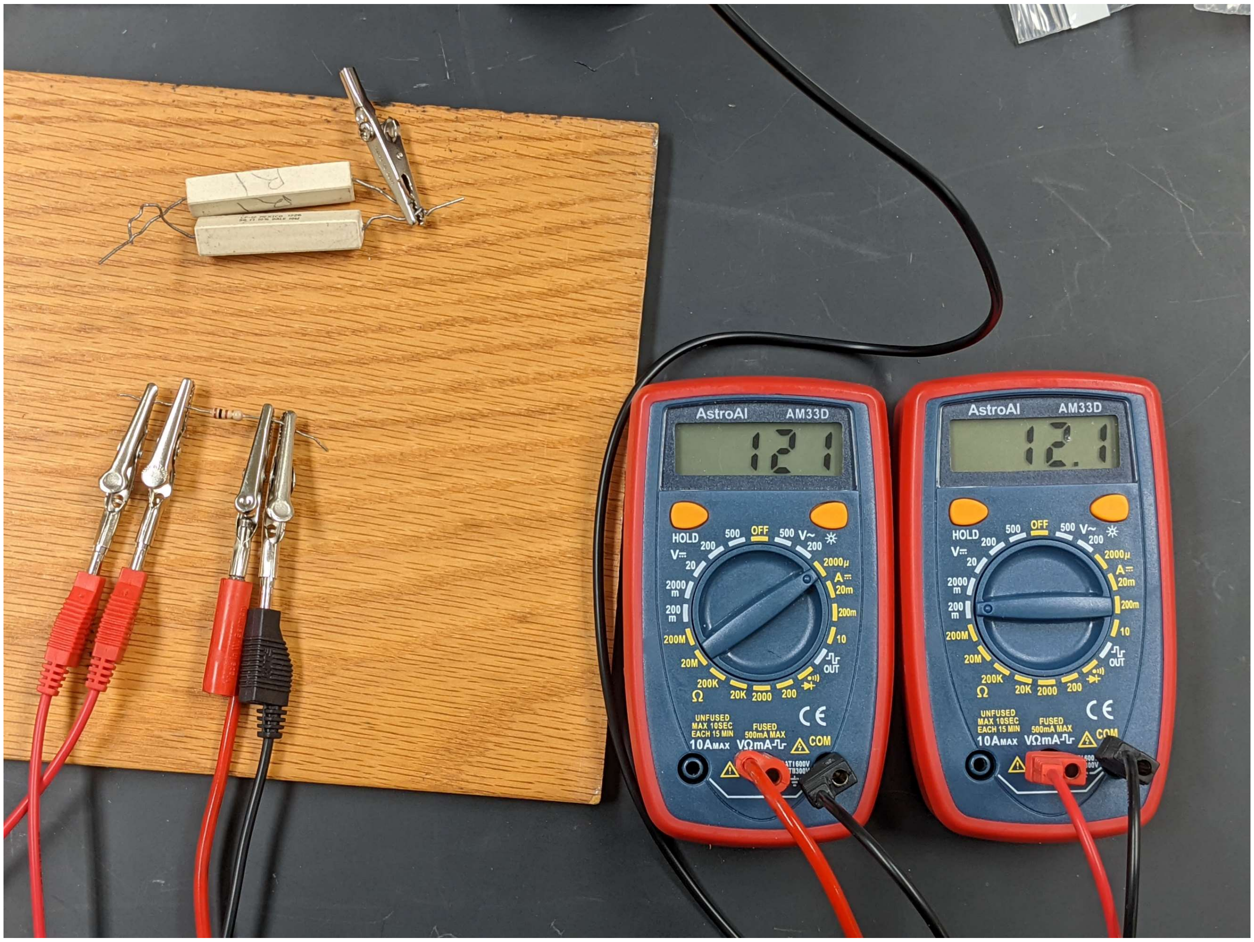
500mA MAX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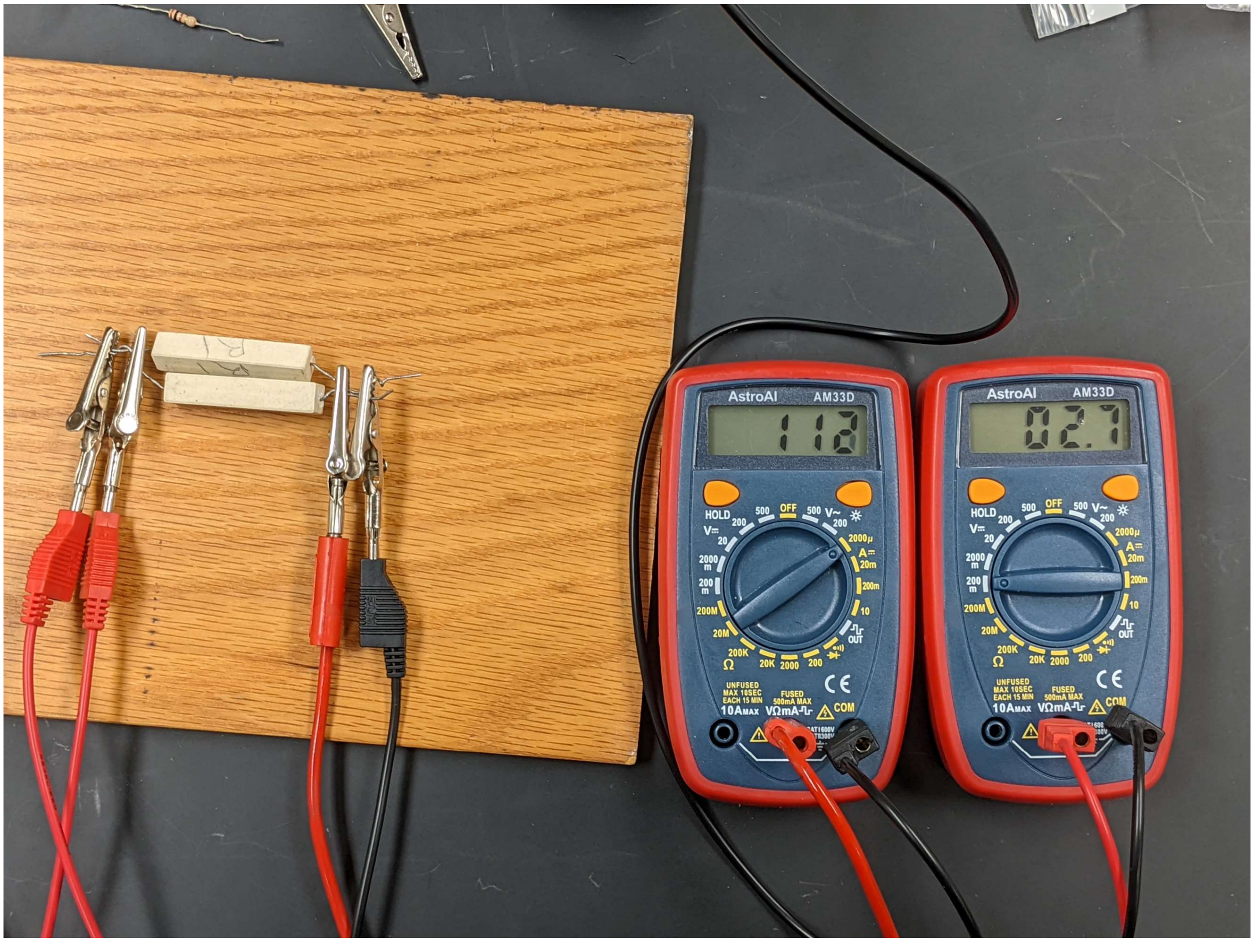
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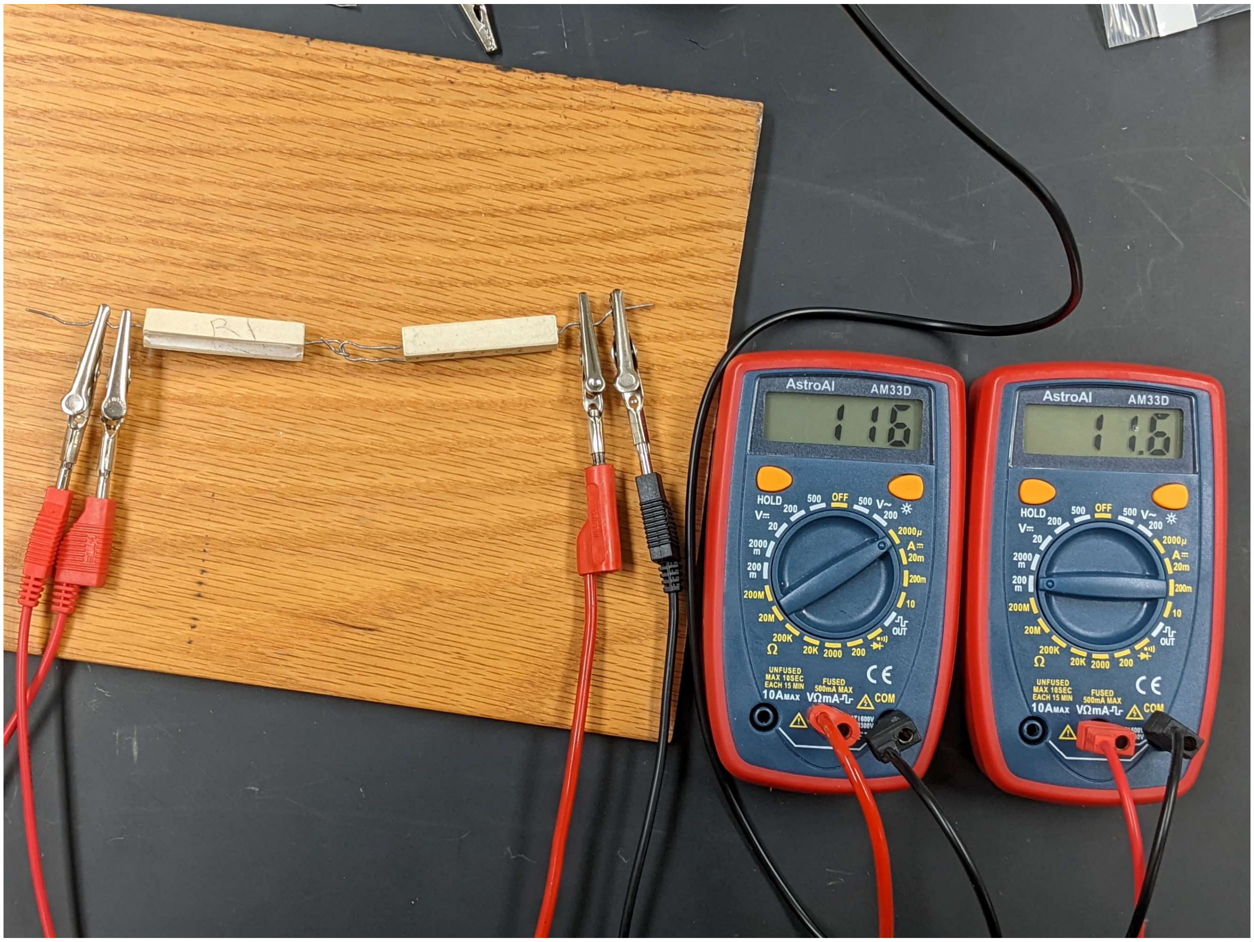
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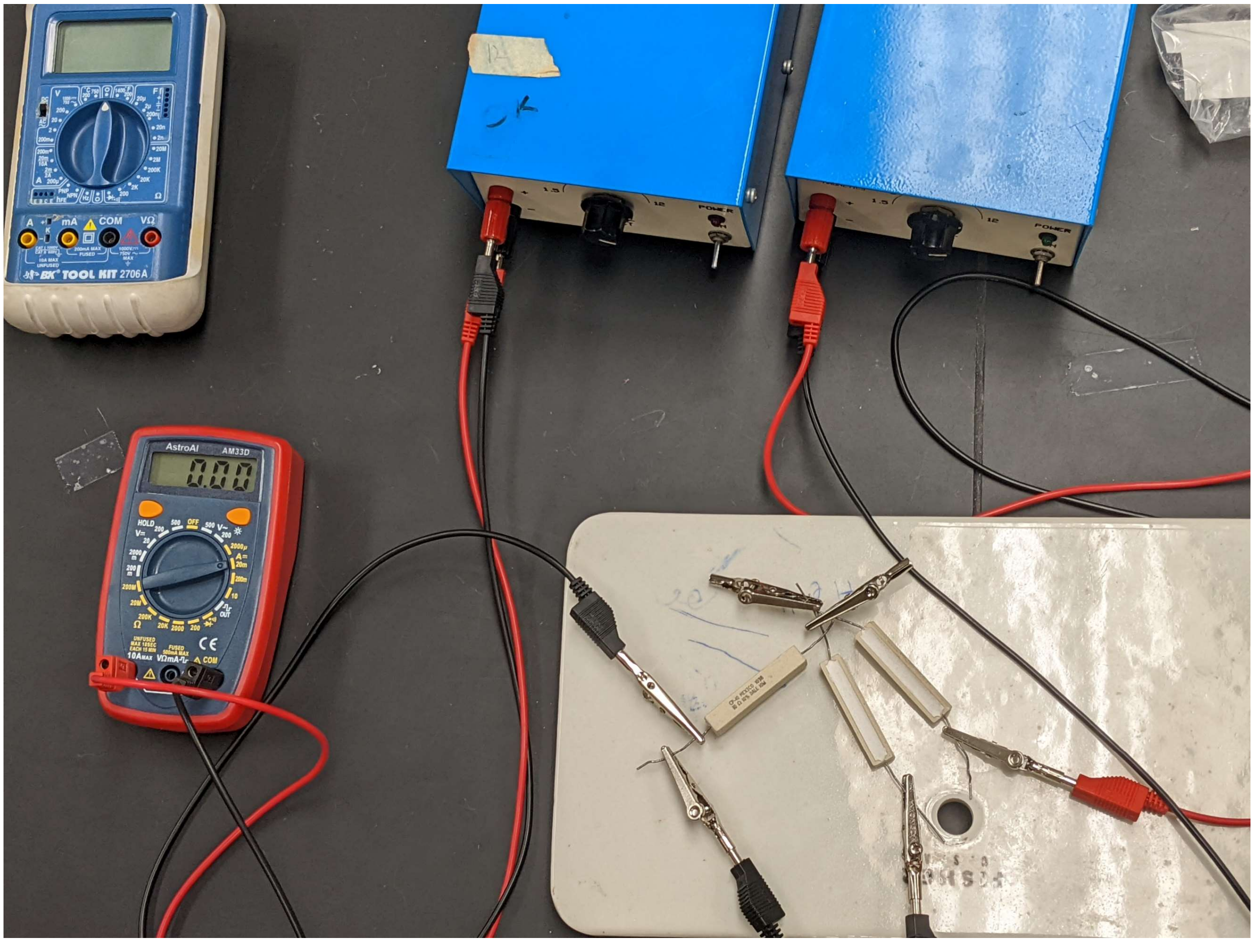
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